Pressurized Water Reactor
B&W Technology
Crosstraining Course Manual

Chapter 20.0

B&W Plant Differences

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20.0 B&W PLANT DIFFERENCES

Introduction:

The major differences between the B&W plant described in this manual and the operating B&W plants are: (1) normal operating parameters, (2) the reactor protection system design, and (3) the Integrated Control System (ICS). Minor differences in reactor vessel and fuel assembly construction also exist. These differences, as well as known dissimilarities, between operating B&W units will be described in this chapter.

20.1 Normal Operating Parameters

Babcock and Wilcox designates generations of plants by the number of fuel assemblies contained in the core. All of the operating B&W plants in the U.S. are 177 fuel assembly (177FA) units. Table 20-1 lists the major characteristics of each B&W unit.

The temperature program for a typical 177FA unit starts at 532°F at zero power, and temperature is escalated to 579°F as power changes from 0 to 15%. Of course, a constant T_{avg} is maintained at 579°F by the ICS from 15% to 100%. Figure 20-1 graphs hot leg, cold leg, and average temperature versus power. Since steam pressure is a function of no-load T_{avg}, normal operating steam pressure is 885 psig (900 psia). Normal reactor coolant pressure is 2155 psig and is sensed on one of the two hot legs.   Pressurizer pressure is not measured in the 177FA units.

20.2 Reactor Protection and Engineered Safety Features Actuation Systems

20.2.1 Reactor Protection System

Chapter 10.1 describes the functioning of the 177FA Reactor Protection System (RPS). The 205FA RPS operates almost identically. However, there are differences in trip functions. The 205FA RPS contains a microprocessor that generates DNBR, offset, and power to ΔT trips. The offset trip prevents local heat generation from exceeding the centerline fuel limit, while the power to ΔT trip provides startup protection. High and low pressurizer level trips are provided in the 205FA RPS as diverse trips to the high and low RCS pressure trips. In addition, the high RB pressure trip is eliminated in the 205FA RPS design. 205FA RPS differences are discussed here to provide the student with a list of the trips that affect the transients in chapter 19 of this manual. Table 20-2 compares the trip functions of the two RPS designs.

20.2.2 Engineered Safety Features Actuation System

The Engineered Safety Features Actuation Systems (ESFAS) at the operating plants are essentially identical to the ESFAS described in chapter 10.2 with the exception of Davis-Besse and Crystal River. The Davis-Besse ESFAS system has a 2-out-of-4 actuation logic. According to the Updated Safety Analysis Report (USAR), the Crystal

River ESFAS is a 2-out-of-3 system, but does not contain unit control modules. Override switches for the entire system are installed. Also, high and low pressure injection are bypassed separately; high pressure at 1700 psig, and low pressure at 900 psig.

20.3 Integrated Control System (ICS)

The major differences in the ICS can be found in the integrated master, the feedwater assemblies, and the unit load demand. Typically, the integrated master controls fewer turbine bypass and steam dump valves while the feedwater demand subassembly has the addition of high OTSG level limits. In addition, two methods of feedwater flow control exist. The B&W units with the exception of Davis Besse, utilize a core thermal feedback circuit to the unit load demand.

20.3.1 Integrated Master

Since the control of the turbine, the "kicker" signal, the calibrating integral, and the characterization of the feedwater and reactor demand signals are identical to those discussed in chapter 9, only the control of the turbine bypass and atmospheric dump valves will be discussed in this section. As shown on Figure 20-2, the header pressure setpoint (885 psig) is combined with one of three bias values. If the reactor is not tripped and the turbine is tripped, then a zero bias is added to the header pressure error. If neither the reactor nor turbine is tripped, then 50 psig is added to the turbine header pressure error. Finally, if the reactor is tripped, 125 psig is added to the header pressure error.

The zero bias value is selected by the ICS during plant startups and maintains a header pressure of 885 psig. When the unit load demand is greater than 15%, the turbine bypass valves are closed, and there is less than a 10-psig header pressure error, the 50-psig bias value will be selected. This bias value will cause turbine bypass or atmospheric dump valve actuation at 935 psig and provides steam header relief. The 125 bias value is selected when the reactor trips. This selection biases the header pressure setpoint up to 1010 psig and minimizes the reduction in T_{avg} and the associated outsurge from the pressurizer. Normal post-trip T_{avg} is approximately 550°F.

The bias value selection relay (T_1) determines the value of bias that will be added to the header pressure setpoint. The header pressure setpoint, and the appropriate bias value is compared with actual header pressure in difference amplifiers. Each difference amplifier also receives an input from its associated header pressure transmitter. (The steam headers at some units are not cross-connected unless the turbine throttle and control valves are open.) The error signal from the comparison of header pressure setpoint plus bias and actual header pressure is routed to a high select unit via hand-automatic stations that allow the operator to manually control the steam valves.

In the high select unit, the higher of either turbine header pressure error or OTSG pressure error is selected for valve control. OTSG pressure error is determined by comparing a fixed setpoint of 1025 psig with actual OTSG pressure. The 1025 psig

setpoint sets an upper limit of steam pressure for transients that do not actuate the steam line safety valves.

The outputs of the high select units are routed to the turbine bypass valves or the atmospheric dump valves by relays T_2 and T_3. If the condenser is able to accept steam from the turbine bypass valves, as determined by condenser vacuum and circulating water flow, then relay T_3 will allow the turbine bypass valves to open. If condenser vacuum or circulating water flow is lost, then relay T_3 will transfer a zero demand to the bypass valves, while relay T_2 will transfer the valve demand signal to the atmospheric dumps.

20.3.2 Feedwater Subassembly

The level in the OTSG must not be allowed to cover the steam aspirating ports; therefore, a circuit must be added to limit level in the steam generators. The circuit is located downstream of the feedwater error amplifier and consists of an input from the operating range level detector, an error amplifier that compares actual operate range level with a fixed setpoint, and a low select amplifier. This circuit is shown in Figure 20-3. If actual operating range level is equal to or greater than the fixed setpoint, the low select amplifier will select the output of the high level limits circuit for the control of feedwater flow. In other words, feedwater flow will be limited to a value that maintains OTSG level at a value less than or equal to the high level limits setpoint.

20.3.3 Feedwater Flow Control

Most of the operating B&W units control feedwater flow by the methods described in chapter 9; however, Arkansas Nuclear One - Unit 1 and Crystal River Unit 3 control feedwater flow differently. These units have three feedwater flow control valves instead of two, and a cross-connect valve that is closed above 50% feedwater demand is also installed (Figure 20-4). The startup feedwater regulating valve is used to control feedwater flow when the steam generator is on low level limits and with low flow demands. When the startup valve reaches 80%, the low load block valve opens, and the low load control valve controls feedwater flow from approximately 15% to 50% power. At 50% power, the main feedwater block valve opens and the cross-connect valve is closed. From 50% to 100% load, feedwater flow is controlled by varying main feedwater pump speed.

20.3.4 Unit Load Demand (ULD) Differences

Oconee, ANO-1, TMI, and Crystal River utilize a core thermal power (CTP) feedback circuit which inputs into the ULD. The core thermal power is the calculated total core power in megawatts thermal. The ULD will be operated in automatic with the CTP causing minor corrections for the generated megawatts via ICS. This allows the units to operate closer to their licensed rated thermal power without exceeding those limits. Davis Besse does not have a CTP feedback circuit. The ULD is always operated in manual.

20.3.5 BTU Limits

The BTU Limit circuit is still active at TMI. When a BTU limit occurs the feedwater subsystem will reduce the total feedwater flow in an effort to increase the amount of superheat. Crystal River, ANO-1, and Davis Besse use the BTU Limit only as an alarm function.

Oconee's ACS (explained in Chapter 21) uses a FW Temperature Modification circuit to ensure the minimum amount of superheat is maintained.

20.3.6 ICS and NNI Inputs

Since pressurizer pressure is not measured on the 177FA plants, RCS pressure from two of the RPS channels is supplied to the NNI system, via buffer amplifiers, for the control of pressure. Also, RCS flow is supplied to the ICS and NNI systems from the RPS for indication and control functions.

Power range inputs also differ from unit to unit. Some units have a separate power range detector that supplies the reactor power input to the ICS, while other units use some sort of averaging and high select units.

20.4 Reactor Coolant System Differences

20.4.1 Reactor Vessel Construction

There are two differences (besides dimensional variations) between the 205FA reactor vessel and the 177FA reactor vessel. First, the 177FA vessel (Figure 20-7) contains a thermal shield that is installed to minimize the effects of neutron and gamma reactions in the reactor vessel. Secondly, the core support assembly is constructed in two pieces. The first part of the core support assembly is called the core support barrel and consists of the flow distributor, the lower grid, and a right circular cylinder that houses the baffle plates and fuel assemblies. The thermal shield is attached to the core support barrel. The second part of the core support assembly is called the core support shield and is bolted to the top of the core support barrel. After initial assembly, the core support barrel and the core support shield may be thought of as one component.

20.4.2 Fuel Assemblies and Control Rods

The 177FA fuel assembly has a 15 X 15 array of fuel pins and guide tubes instead of a 17 X 17 array. The fuel assembly spring design utilizes a single spring instead of the four springs that are installed on the 205FA design (see Figure 20-5). In addition, the control rods have 16 fingers instead of 24 fingers.

20.4.3 Loop Designs

All of the 177FA plants with the exception of Davis-Besse are of the lowered loop design (Figure 20-6). Davis-Besse has a raised loop design similar to the design discussed in the technology manual. The design was changed to a raised loop design to improve the natural circulation response of the plant.**20.5 Emergency Feedwater (EFW) Differences**

20.5   Emergency Feedwater (EFW) Differences

Davis Besse's FSAR calls EFW "Auxiliary Feedwater" (AFW) implying that the AFW system is the standby emergency feed source for a loss of feed event. The other B&W refer to the emergency standby feedwater system as EFW.

20.5.1 EFW Mechanical Component Differences

Table 20-1 illustrates the EFW pump differences at the five B&W sites.

The five B&W plant sites utilize solenoid modulated feedwater control valves to precisely maintain OTSG level at the desired setpoint via the level control circuit. The differences would be the number of control valves used for OTSG level control.

20.5.2 Emergency Feedwater Initiation and Control (EFIC)

ANO-1 and Crystal River utilize EFIC to maintain OTSG water levels by ramping EFW flow based on the current OTSG pressure. The Emergency Feedwater Initiation and Control (EFIC) system monitors OTSG level and pressure, MFW pump status, RCP status, AMSAC, and ESAS channels 3 and 4 in order to initiate EFW or OTSG isolation should an actuation setpoint be reached. The EFIC system also provides two controlling functions. OTSG pressure is controlled by operation of the ADV's and OTSG level is controlled via EFW control. See Figure 20-10.

EFIC is designed to protect against the consequences of a simultaneous blowdown of both steam generators. In the event a steam line break occurs, EFIC would automatically initiate action to isolate the faulted steam generator by closing the MSIV, the MFIV, startup and low load feedwater control valves, and the emergency feedwater isolation valves on each line to the degraded OTSG.

The EFIC System is designed to provide the following:
- Initiation of EFW.
- Control of EFW flow rate to the steam generators to control level atappropriate setpoints.
- Steam generator fill rate control when required to minimize overcooling.
- The selection of the "Good" steam generator under conditions of steam linebreak or main feedwater or emergency feedwater line break downstream of   the last check valve.
- Control of the atmospheric dump valves**.**

- Signals for isolation of the main steam and main feedwater lines of a depressurized steam generator.

The EFW flow rate is controlled by determining the pressure in the OTSGs and ramping the flow rate (linear rate of change of flow) to ensure cooldown rates are not exceeded. Figure 20-8 illustrates the linear flowrate relationship. Figure 20-9 illustrates the vector logic that determines which OTSG will be isolated to ensure the faulted OTSG is not fed.

20.6 Digital Control Rod Drive Control System (DCRDCS)

Currently Oconee 1,2,3 has this newer rod control system installed. TMI is scheduled to install a similar system in the fall of 2011. The following section will describe the DCRDCS installed at Oconee Units 1,2,3.

The DCRDCS consists of three basic components: (1) Power Supplies; (2) System Logic; and (3) Trip Breakers. The major change for the DCRDCS is the power supply and system logic circuits. The B&W rod control interlocks and automatic features have not changed. The reactor trip breakers remain the same design. Figures 20-11,12,13 illustrates the newer rod control design.

20.6.1 DCRDCS Power Supplies

The power supplies consist of 138 Single Rod Power Supplies (SRPS), with two identical halves wired as a redundant pair and connected to each Control Rod Drive Mechanism (CRDM). Each SRPS uses a six-phase half-wave (Silicon Controlled Rectifier) SCR design. (Figures 20-11 & 20-12)

In each half of a SRPS, rectification and switching of power is accomplished through the use of SCRs. The switching sequentially energizes first two, then three, then two of the six CRDM stator motor windings in stepping motor fashion to produce the magnetic field for the control rod assembly motor to position the control rod assembly (CRA). Switching is achieved by gating the six SCRs on for the period each winding must be energized. As each of the six winding utilize SCR to supply power, six gating signals are required. (Figure 20-13)

The gating signals for the SRPS are generated by the programmable logic controller (PLC) using software containing logic to accept automatic commands from the ICS, or direct manual commands from the Operator Control Panel (OCP) The OCP would be the same as the Diamond Panel in older B&W rod control systems. These commands are converted to sequential digital outputs which cause the mechanism motors to step at the proper speed and direction to provide the 3-2 hold control, which ensures two-coils are energized when there are no commands. If one coil becomes de-energized the control rod position will be maintained but cannot be exercised.

The PLC is also known as a triple modular redundant (TMR) controller using a triplicate processor running in parallel, with redundant and automatic selection of the "good" signal in the event of failure or malfunction of the controlling signal "slice". An auctioneering network determines if any anomalies exist and selects the most credible (via a two-out-of-

three voting network) of the three available signals. Each processor executes the application program simultaneously and independently. The rod movement signals from the TMR Controller control the pulse generator portion of the Pulse Generator/Monitoring Module (PG/M Module), which generates the 6-phase trigger signals. These trigger signals are fed to the SRPS gate drives, and finally to the Power Modules of the SRPS, which produce the CRDM drive pulses. Redundant power supplies are used for all CRDMs, and each is capable of carrying the full load and each is fed from separate power sources with a common SCR gating signal control source.

20.6.2 System Logic

The system logic encompasses those functions which command control rod motion in the manual or automatic modes of operation, including group sequencing, safety and protection features, and the manual trip function. Major components of the system are the RPS interface Trip Breakers, Position Indication (PI) Panel, OCP, TMR Controllers, and Engineering Work Station (EWS) - for software control inputs, and the SRPS. (a second PLC is devoted exclusively to processing absolute and relative control rod position indication signals). (Figure 20-14)

The sequence section of the logic system utilizes rod position signals to generate control interlocks which regulate rod group withdrawal and insertion. The sequence logic applies in both automatic and manual modes of reactor control, and controls the regulating groups only. Analog position signals are generated by the reed switch matrix on the CRA, and an average group position is generated by an averaging network. This average signal serves as an input to electronic trip units which are activated at approximately 25 and at 75 percent of group rod withdrawal. Two bistable units are provided for each regulating group. When operating in the "sequence mode" mode, the PLC controls sequential withdrawal and insertion of numerically adjacent regulating groups. Two adjacent groups are enabled coincidentally within 25% overlap regions, in order to minimize effects of lower rod worth at their upper and lower extremes in travel.

The automatic sequencer circuit can control only rod Groups 5, 6, and 7. The safety rod groups, Groups 1 through 4, are controlled manually, one group at a time. In addition, the operator must select the safety group to be controlled and transfer it to the auxiliary power supply before control is possible. There is no way in which the automatic sequencer can affect the operations required to move the safety rods. Automatic operation of rods can only be commanded by the ICS when the Control Rod Drive System is in the automatic mode. These commands can only affect rod Groups 5, 6, and 7.

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TABLE 20-1 B&W PLANT COMPARISONS

Plant	Doc #	Mw(th)	Mw(e)	Turbine	Cond/UHS	RCPs	Diesel (kw)	AFW/ EFW	EFIC	Bypass/Dumps (% steam flow)
ANO-1	50-313	2568	911	W	River/Pond	Byron-Jackson	2750	1(MD)/1(TD)	Yes	15.8/6.2
Crystal River-3	50-302	2609	924	W	Sea/Sea	Byron-Jackson	2750	1(Diesel)/1(TD)	Yes	15/7.5
Davis-Besse	50-346	2772	906	GE	Tower/Lake	Byron-Jackson	2600	2 (TD)	No	25/10
Oconee-1	50-269	2568	846	GE	Lake/Lake	Westinghouse	Hydro	2(MD)/1(TD)	No	40/-
Oconee-2	50-270	2568	846	GE	Lake/Lake	Bingham	Hydro	2(MD)/1(TD)	No	40/-
Oconee-3	50-287	2568	846	GE	Lake/Lake	Bingham	Hydro	2(MD)/1(TD)	No	40/-
TMI-1	50-289	2568	808	GE	Tower/River	Westinghouse	2750	2(MD)/1(TD)	No	21.4/6.3
WNP-1 (TTC Sim.)	50-460	3760	1338	W	Tower/Pond	Bingham	7060	2(MD)/1(TD)	No	18.5/78.4

General Notes:
1. Davis-Besse has a separate high pressure injection system. The discharge of the HPI pumps is approximately 1600 psig.
2. ANO-1 and Crystal River-3 control feedwater flow above 50% power by varying MFP speed.
3. The Oconee units do not have main steam isolation valves. The piping from the OTSGs to the turbine is Seismic Category I. The site has one Safe Shutdown Diesel AFW pump which can supply any unit, any OTSG.
4. Crystal River has one non-safety motor-driven AFW pump and one Appendix R motor-driven AFW pump with a dedicated diesel generator.
5. Davis-Besse has one non-safety motor-driven AFW pump.

TABLE 20-2 RPS COMPARISONS

177FA RPS Trips	205FA RPS Trips
High Reactor Power	High Reactor Power
High RCS Pressure	High RCS Pressure
Low RCS Pressure	Low RCS Pressure
Variable Low RCS Pressure	*DNBR
Flux/Imbalance/Flow	*Offset, Power to Flow
Power to Pumps	*DNBR, *RCP Status
High Outlet Temperature	High Outlet Temperature
High Reactor Building Pressure	No Equivalent Trip
Anticipatory Loss of MFW Pumps Turbine Trip	To Be Determined
	High Pressurizer Level Low Pressurizer Level *Power to ΔT

* These trips are calculated by a safety-related digital computer.
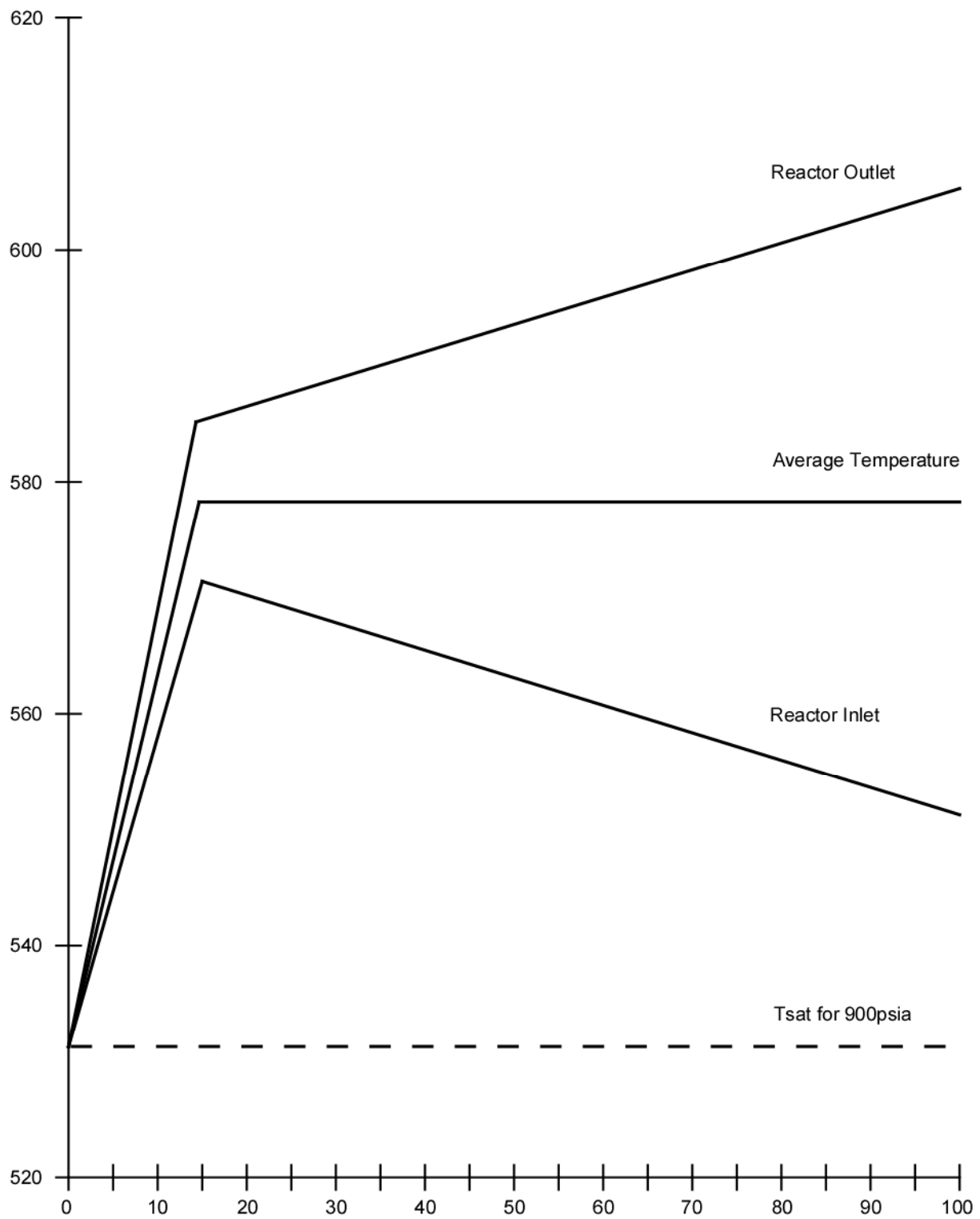
Figure 20-1   RCS Temperatures vs. Power
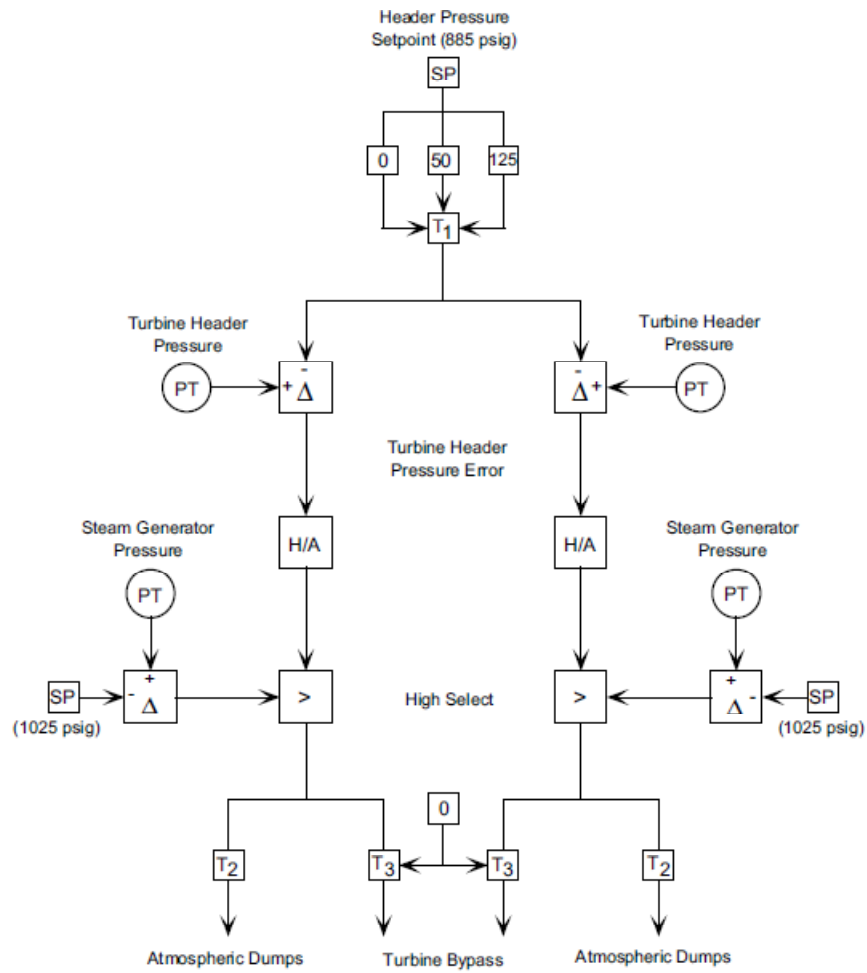
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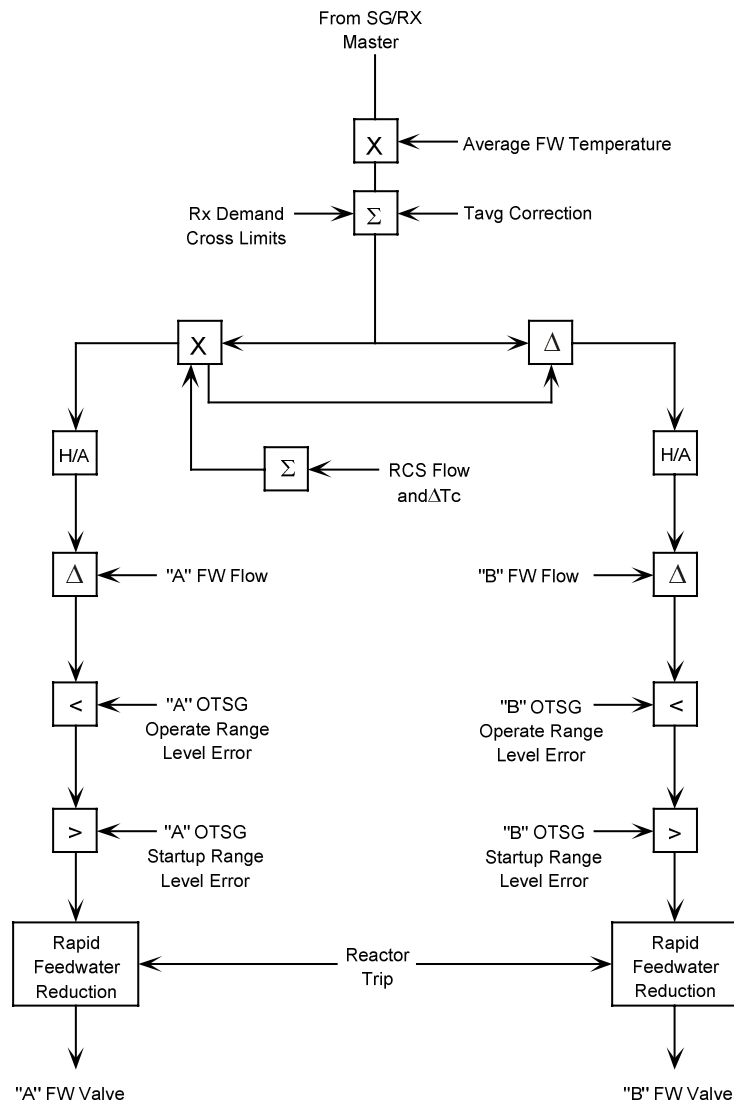**Figure 20-2   Header Pressure Control**

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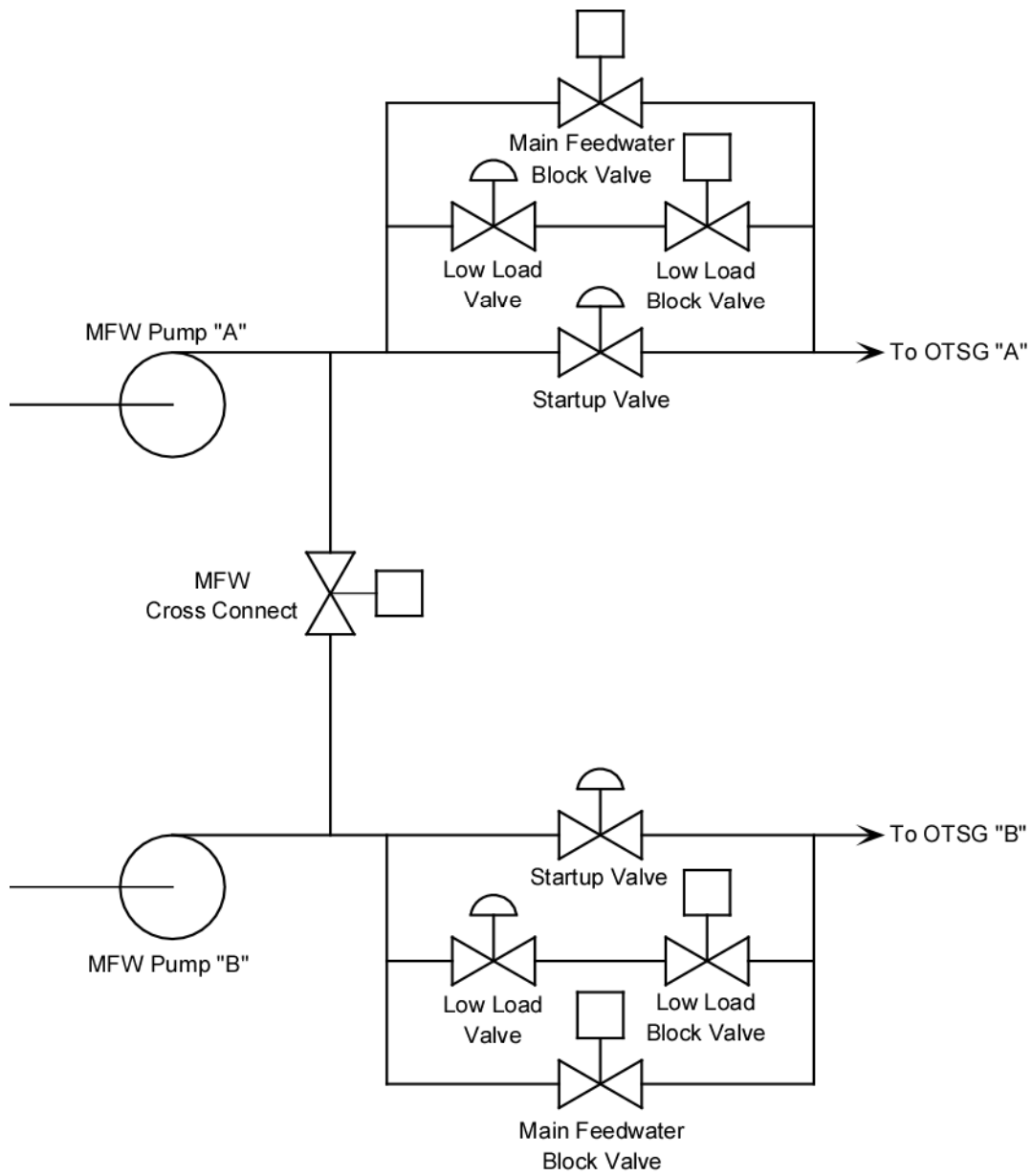
Figure 20-3   177FA FW Demand

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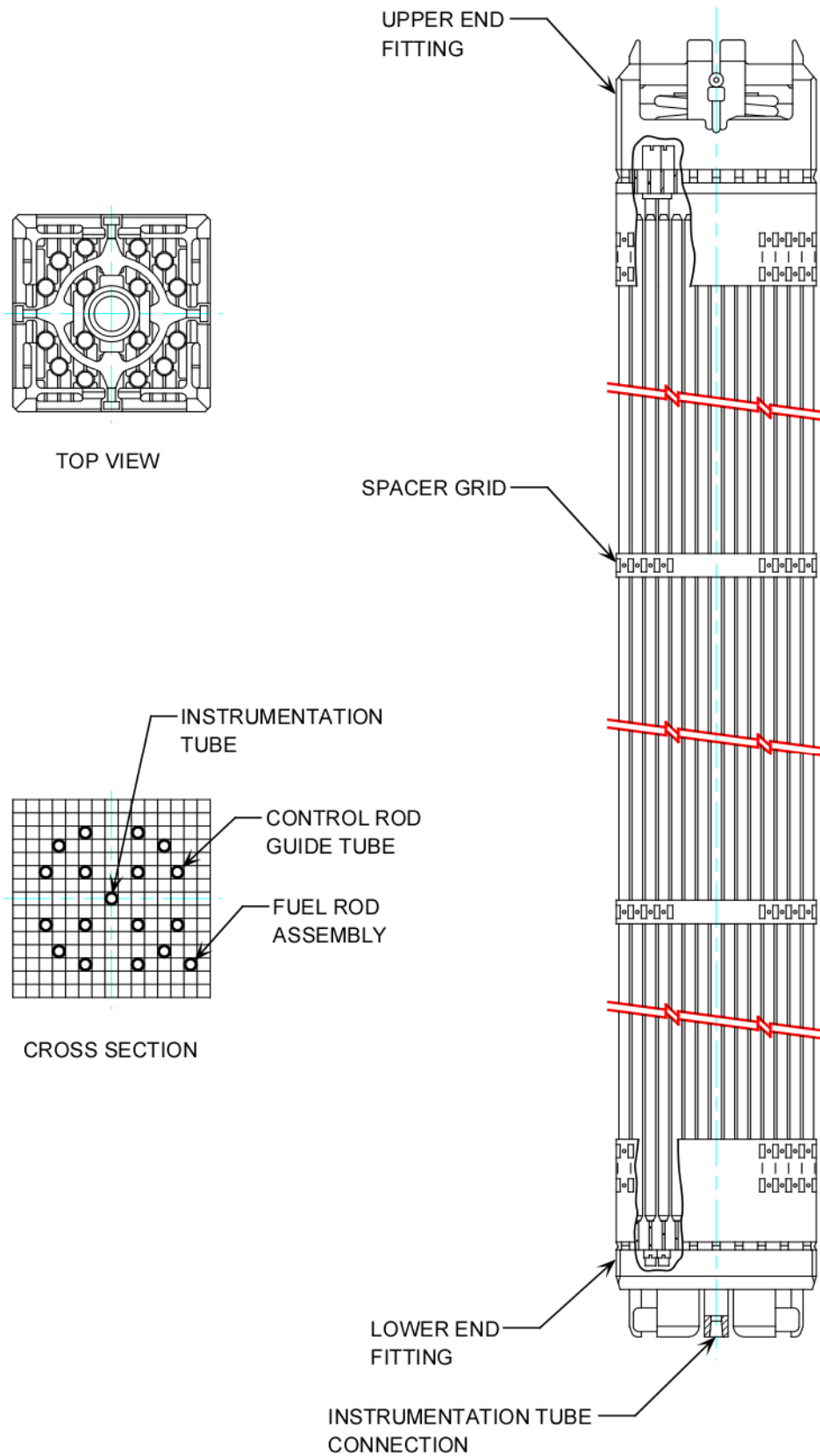**Figure 20-4   MFW Regulating Valves**

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UPPER END FITTING

TOP VIEW

INSTRUMENTATION TUBE

CONTROL ROD GUIDE TUBE

FUEL ROD ASSEMBLY

CROSS SECTION

SPACER GRID

LOWER END FITTING

INSTRUMENTATION TUBE CONNECTION

Figure 20-5   Fuel Assembly

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STEAM
GENERATOR

STEAM
GENERATOR

REACTOR

REACTOR
COOLANT
PUMP

8'-0"

31'-0"

9'-0"

24'-0"

5'-0"

79'-8-1/2"
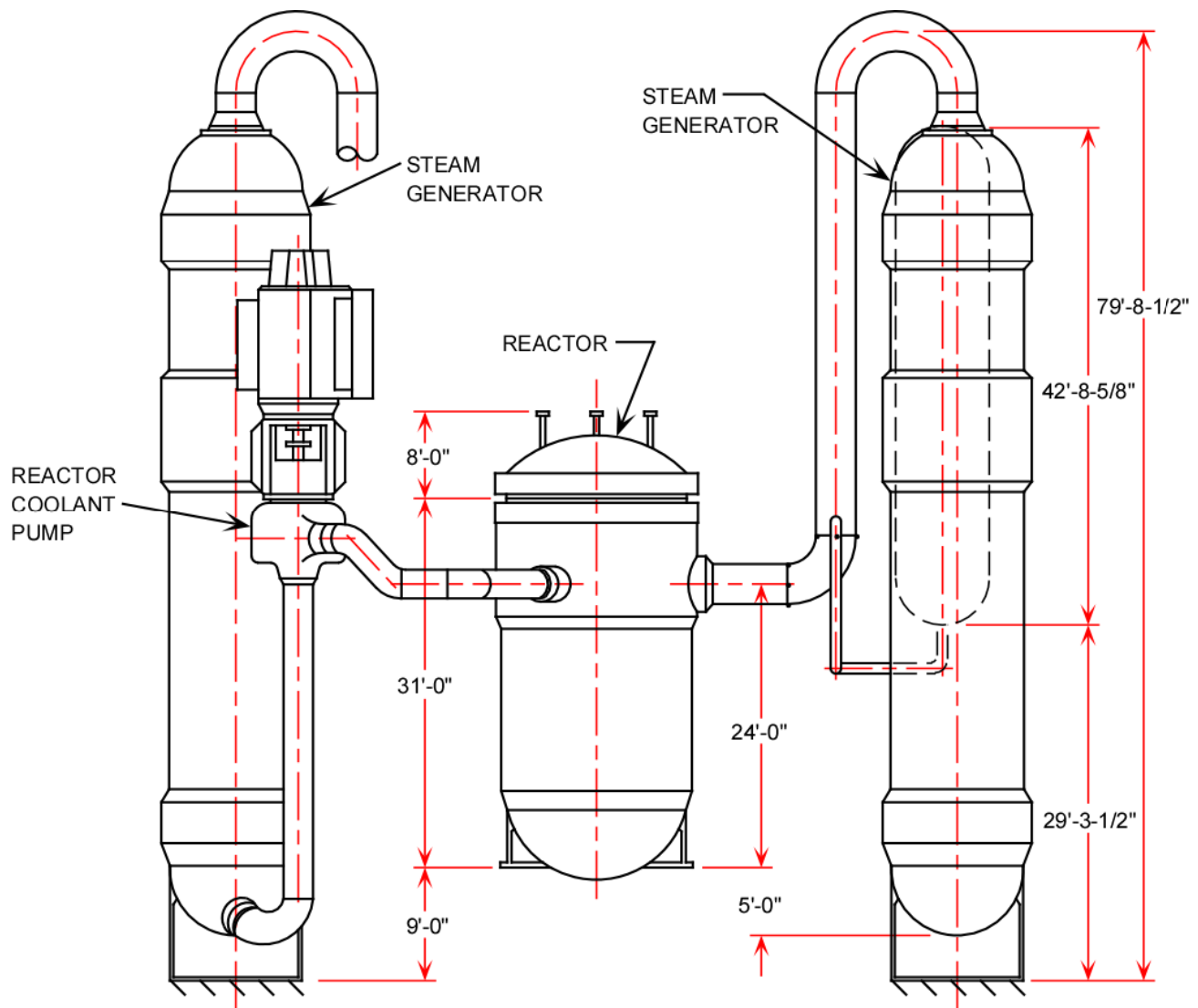
42'-8-5/8"

29'-3-1/2"

Figure 20-6   Lowered Loop NSSS
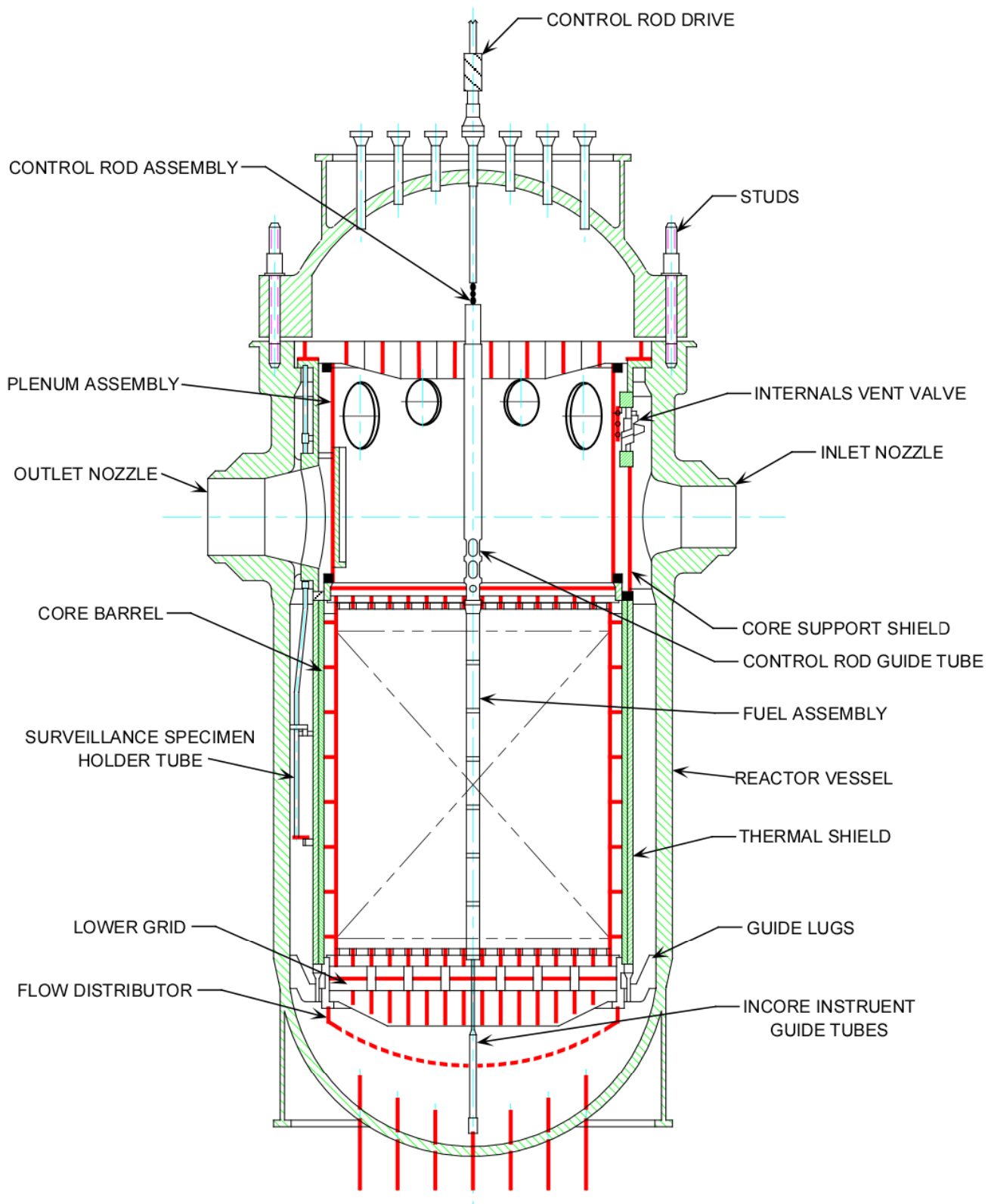
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Figure 20-7   177 FA Reactor Vessel
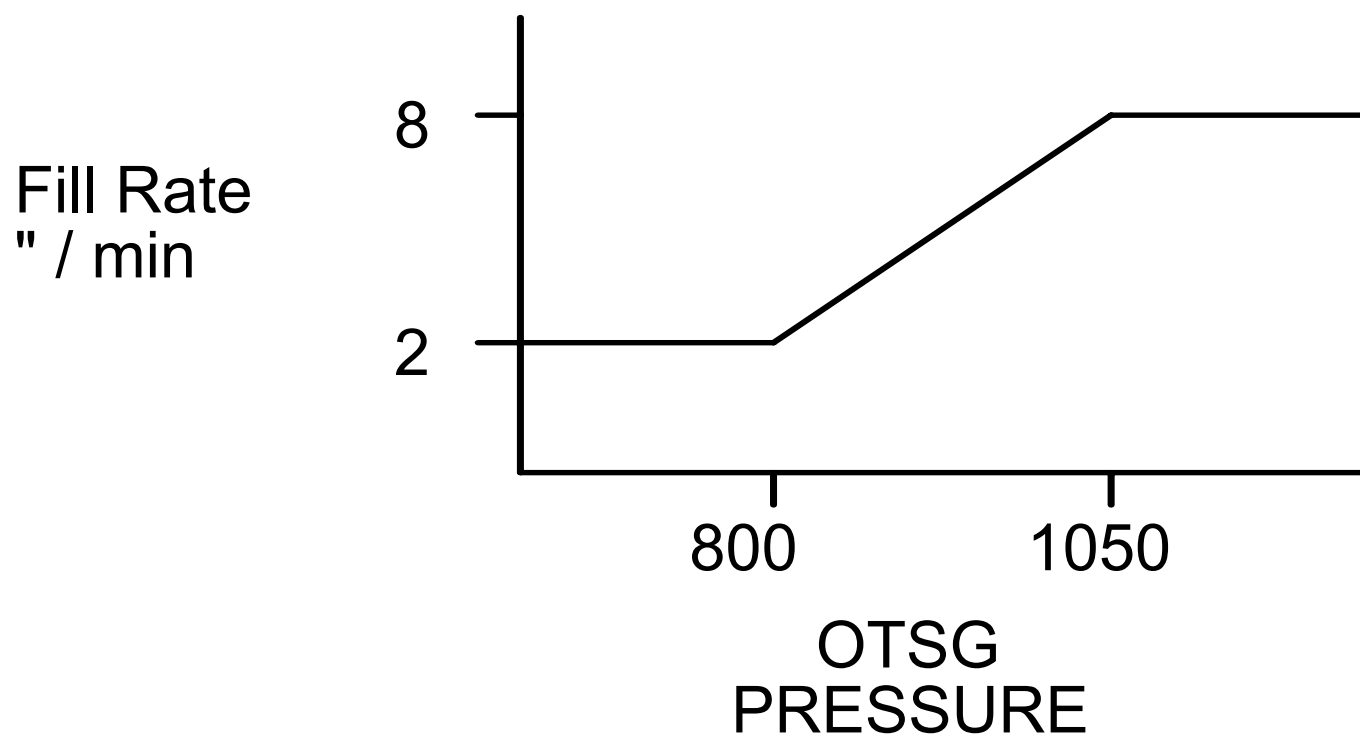
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Figure 20-8   EFIC Linear Graph of EFW Flow Control
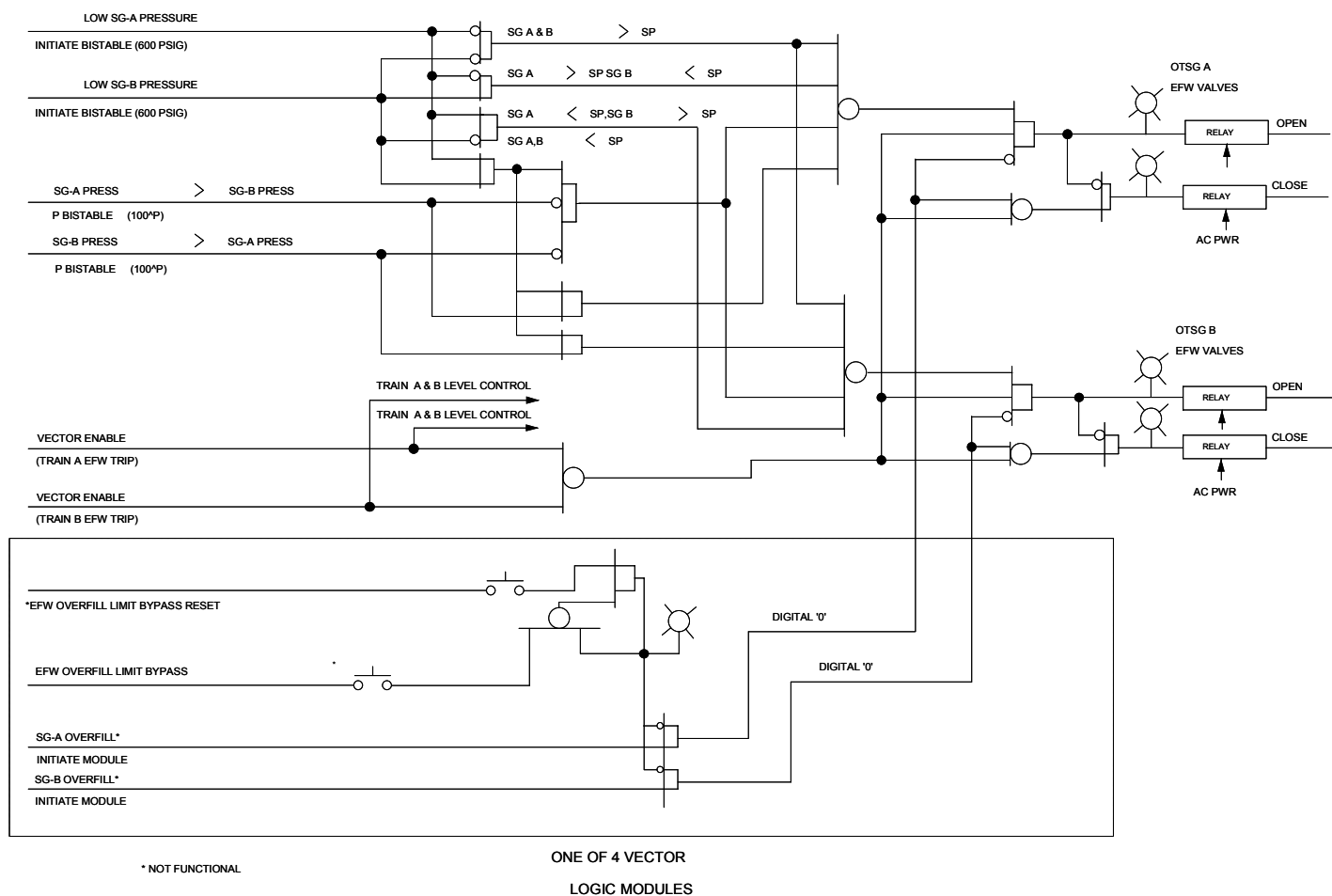
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Figure 20-9   EFIC Vector Control Logic
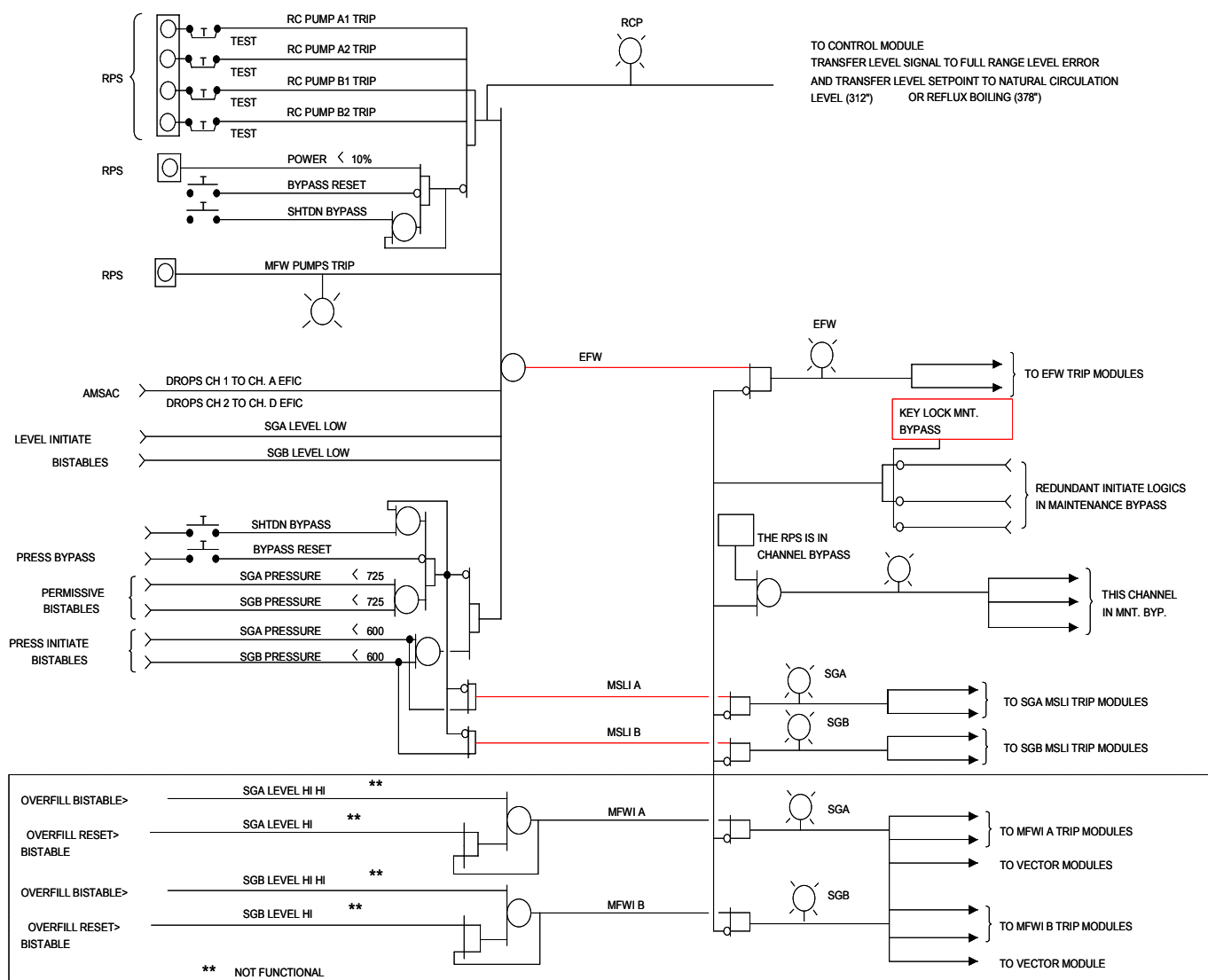
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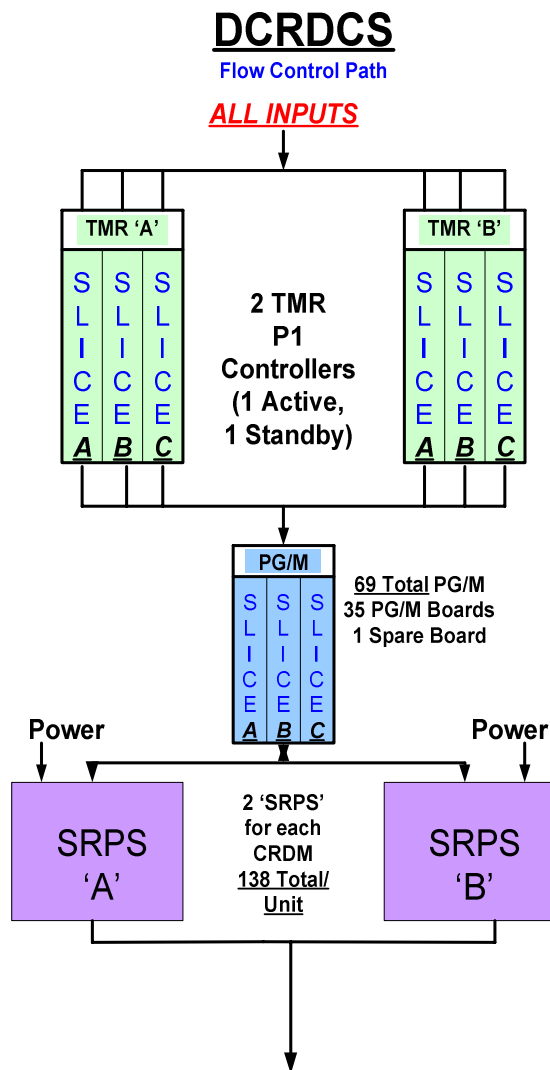**Figure 20-10   EFIC Initiation Logic**

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DCRDCS

Flow Control Path

ALL INPUTS

TMR 'A'			2 TMR P1 Controllers (1 Active, 1 Standby)	TMR 'B'		
S L I C E A	S L I C E B	S L I C E C		S L I C E A	S L I C E B	S L I C E C

PG/M

S L I C E A	S L I C E B	S L I C E C

69 Total PG/M
35 PG/M Boards
1 Spare Board

Power

Power

SRPS 'A'	2 'SRPS' for each CRDM 138 Total/ Unit	SRPS 'B'

Figure 20-11   DCRDCS Simplified Diagram

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CRD Power Configuration

NORMAL

1,3X9
600 Vac

ALTERNATE

2X1,2X2
600 Vac

DCRDCS
120v/1 phase

Breaker 'A'

Breaker 'B'

Breaker 'C'

Breaker 'D'

Gating Input SCRs from DCRDCS

Voltage Regulator

Voltage Regulator

Gating Input SCRs from DCRDCS

DSS 1 & 2
Electronic Trip
'E' 2450 psig

6 φ 100 Vac regulated

6 φ 100 Vac regulated

DSS 1 & 2
Electronic Trip
'F' 2450 psig

SRPS 'A'
Single Rod Power Supply

SRPS 'B'
Single Rod Power Supply

CRDM **M**

*

Figure 20-12   Digital Rod Control Power Diagram

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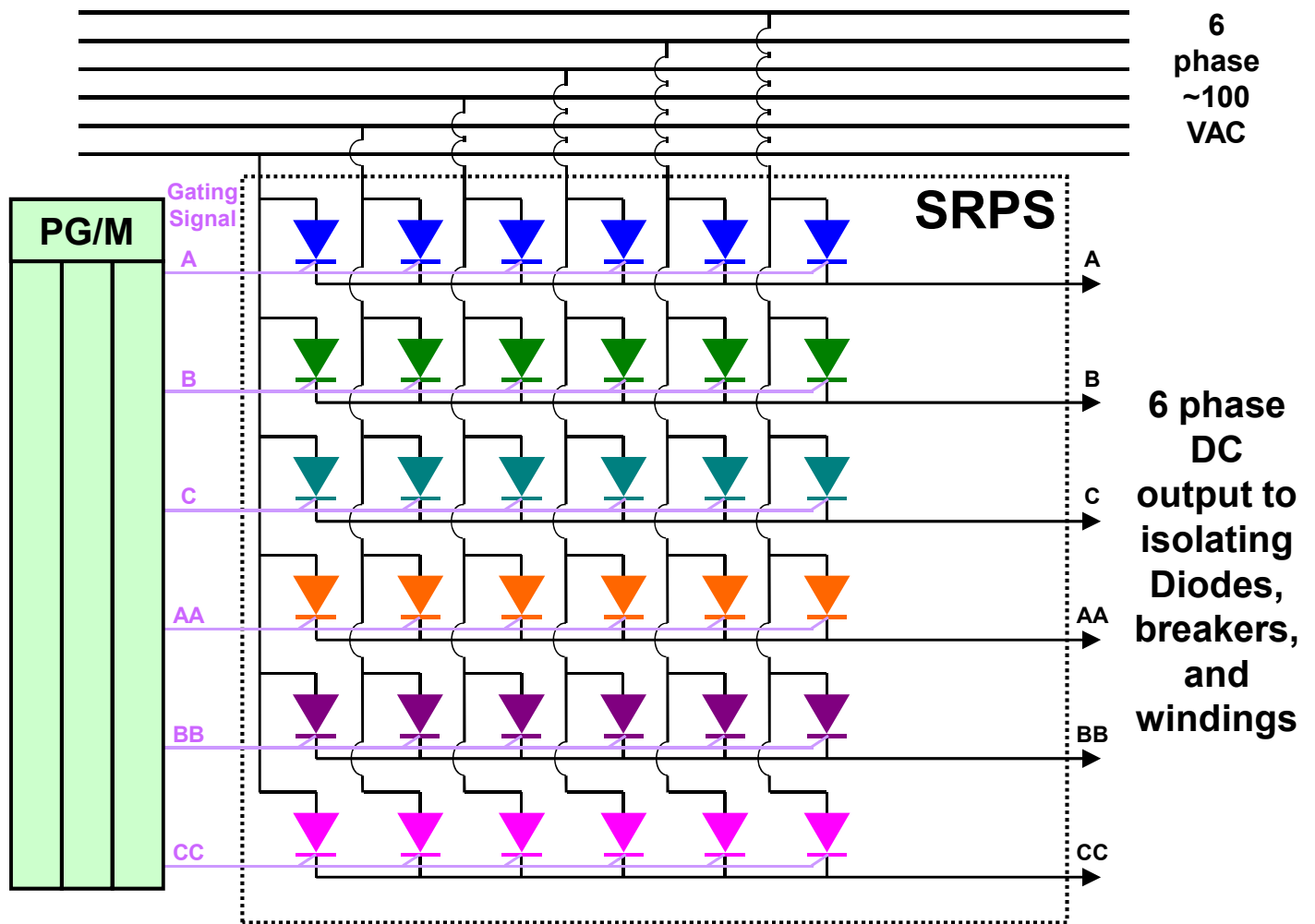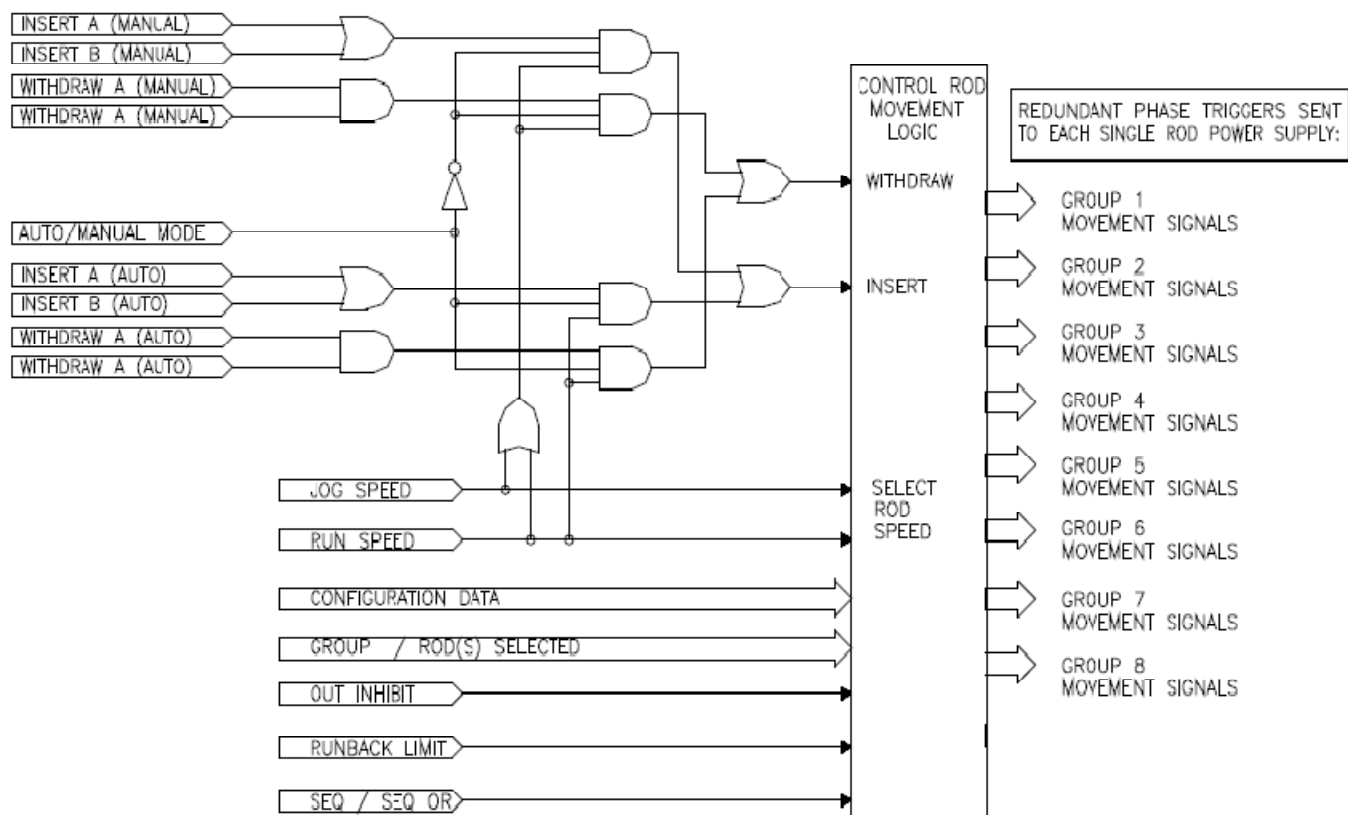**Figure 20-13   Six Phase Signal Generation**

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Figure 20-14   System Logic Diagram

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